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(54) Water soluble polymers and dispersions containing them

Wasserlösliche Polymere und sie enthaltende Dispersionen

Polymères solubles dans l'eau et dispersions les contenant

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- ABSTRACT BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, vol. 54, no. 7, January 1984, page 749, no. 6914, Appleton, Wisconsin, US; J.-M. LAMARCHE et al.: "Influence of molecular weight of sodium polyacrylate in calcium carbonate aqueous dispersions", & INDUSTRIAL & ENGINEERING CHEMISTRY PRODUCT RESEARCH & DEVELOPMENT, AMERICAN CHEMICAL SOCIETY, N.W. WASHINGTON D.C., 20036 USA - vol. 22, no 1 (March 1983), pages 123-126
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Description

It is well known that low molecular weight water soluble polymers, and especially such polymers containing acidic groups that may have been partially or completely neutralised, are of value as pigment dispersants (including grinding aids). The polymers generally have a molecular weight (weight average molecular weight, Mw) of 1,000 to 10,000. However, the polymer will always consist of a blend of molecules of differing molecular weights, according to the number of monomeric units in each molecule. In practice, each commercial polymer is a mixture of molecules having a very wide variation in chain length. For instance a polymer having Mw = 5,000 will generally contain significant amounts of molecules of molecular weight below 1,000 and above 6,000. The extent to which any particular product is formed of molecules of a range of chain lengths is measured by its polydispersity. The polydispersity (PD) of a product is the weight average molecular weight (Mw) divided by the number average molecular weight (Mn). If PD = 1 then the polymer consists entirely of molecules of a single chain length. In practice PD is always much higher, generally above 2.

British Specification No. 1,414,964 describes certain vinyl acetate copolymers for dispersing chalk. In example 2, the polymers are described as having a number average molecular weight of 1,200 to 2,300 and fractional precipitation of the polymer is said to give fractions having number average molecular weight of 150 to 4,000. Slightly different process conditions in Example 3 are said to give a narrower molecular weight distribution and fractions of from 960 to 3,000. The range of molecular weight within each fraction is not quoted. The specification does not disclose the use or properties of any of these fractions but it does attempt to show the polymer of Example 3 (that is a blend of fractions having average molecular weights of 960 to 3,000) has better properties than the product of Example 2 and attributes this to the "effect of optimising the molecular weight distribution". Since the polymers of Examples 2 and 3 could be split into polymer fractions having such a wide range of molecular weights, it is clear that the polymers of Examples 2 and 3 both had high polydispersity values, probably of the order of 2. It is impossible to predict what the polydispersity values would have been of the polymer fractions, as this can vary according to the method of fractionisation, but it was probably in excess of 1.7. There is no suggestion to use the polymer fractions for any purpose.

The products that commercially are most successful as dispersants are polyacrylic acid and acrylic acid 2-acrylamido 2-methyl propane sulphonic acid (AMPS) copolymers. A widely used polyacrylic acid is our product Displex N40 (Displex is a trade mark). The products we sell generally have polydispersity values above 1.8 and indeed most products that are commercially available have polydispersity values above 2. We have regarded it as uneconomic and unnecessary to strive for lower polydispersity values and although batches of polymer having polydispersity slightly below 1.8 are sometimes made by us, during storage they always become blended with batches having higher polydispersity.

It is standard practice to make water soluble acidic polymers, such as polyacrylic acid, by solution polymerisation in which event the solvent may be a blend of water and an organic liquid such as isopropanol. The product of the polymerisation is a solution of polymer together with some oligomer and unreacted monomer.

One process that we have used for removing the unwanted low molecular weight components, i.e. the oligomers and monomer, has involved adding excess sodium hydroxide to the solution so as to neutralise all the acidic groups, and allowing the mixture to separate into an upper isopropanol fraction containing the unwanted low molecular weight components and a lower aqueous fraction containing the desired polymer. This fractionation has been regarded merely as a way of separating the useful polymer from the unwanted by-products. The useful polymer is a blend of molecules of various molecular weights and the PD values quoted above are of the purified polymer.

A particular process for separating unwanted by-products is described in European Patent Publication 46573. In this it is said that an aqueous solution of polyacrylic acid may be neutralised and that the neutralised polymerisate may then be treated in the usual way with polar solvents, methanol, ethanol, propanol, isopropanol, acetone and tetrahydrofuran being mentioned. In the examples 80 grams fully neutralised sodium polyacrylate is fractionated in solution in 500 grams water with 400 grams methanol or 40 grams isopropanol. In each instance the lighter, organic, phase is rejected. This therefore seems to be a conventional fractionation to remove oligomers and the product would therefore be a conventional blend of molecular weights. If the starting polymer mixture is conventional the Mw, Mn and PD values of the extracted polymer will also be conventional, e.g. PD above 1.8.

In U.S. 3,759,860 emulsifiers are described which are oligomers of monomers that can include, for instance, acrylic acid and which are terminated by an alkyl sulphide, alkyl sulphone or alkyl sulfoxide group wherein the alkyl contains 5 to 20 carbon atoms, preferably 6 or 12 carbon atoms. The molecular weight of the oligomers is said to be below 5,000, preferably less than 2,000 and the exemplified alkyl groups will therefore provide the oligomer with a hydrophobe, as is required for the oligomer to function as an emulsifier, and the remainder of the polymer can provide the hydrophile of the emulsifier. These named materials would therefore be unsuitable for use as dispersants for aqueous pigment dispersions. It is stated that the oligomers may have PD less than 2 and frequently as low as 1.4 to 1.5.

In GB 758,986, aqueous pigment dispersions are described using a polymeric dispersant. It is stated that the dispersant must have homogeneity in that it must not impart a viscosity of more than 1,000 cps at 25°C to solutions of its anhydride form at concentrations of 35% in an organic solvent such as dioxane or methyl ethyl ketone. It is further stated that this requirement eliminates mixtures of copolymers which contain some very large molecules and sufficient

very low molecular weight copolymer to bring the apparent molecular weight to the useful range which is defined as being preferably 750 to 5,000. It is further stated that the term homogeneous is used to define copolymers with a narrow distribution of copolymer sizes. No values are quoted for polydispersity but the reference to the avoidance of mixtures of very large molecules with very low molecular weight copolymers indicates that the disclosure is merely saying what has now been recognised for very many years, namely that suitable low molecular weight dispersants should be free of components having such high molecular weight that they will impart significant viscosity. This is of course well known and the presence of such very high molecular weight components is likely to cause, flocculation rather than dispersion. The polymers in GB 758,986 which are described as being homogeneous therefore probably have a polydispersity which is no less than the polydispersity of conventional dispersants, and probably very much more.

Lamarche et al in Ind. Eng. Chem. Prod. Res. Dev. 1983, 22, 123 to 126 examine the influence of molecular weight of sodium polyacrylate in calcium carbonate aqueous dispersions and, in particular, they show data on polymers having molecular weights in the range 700 to 100,000 and they classify these polymers as polymers having "low" or "high" molecular weight distribution or polydispersity index. They state in their conclusion that "very different results can be obtained by changing the molecular weight distribution of the polymer in the size range 2,000 to 20,000". However the only true comparisons between polymers of the same molecular weight and different polydispersity indices are comparisons between polymers F and H which each have a molecular weight of 4,000. The data shows that these two polymers, one being of "low" polydispersity index and the other being "high", give identical absorption values and, presumably therefore, identical dispersing properties. No quantitative values are given for the "low" or "high" polydispersity indices but since polymers of molecular weight 4,000 having "low" and "high" polydispersity indices show the same properties it seems probable that the "low" value is still relatively high, probably at least as high as the conventional polydispersity values for known polyacrylic acid dispersing agents, as discussed above. Where the viscosity measurements are quoted in this article, they are always quoted in respect of calcium carbonate slurry having a solids content of 40%. It is relatively easy to obtain adequate dispersions of such material. A much more stringent requirement is a dispersing agent that will permit the formation of a fluid high solids dispersion (above 72% by weight) ground calcium carbonate particles of which at least 87% by weight are below 2 μ m in size, for instance as described in EP 108842.

It would, of course, be desirable to be able to produce dispersing agents having improved properties so as to facilitate the production or properties of these or other aqueous pigment dispersions. Prior to the invention, we are unaware of anyone ever having proposed that this objective could be achieved commercially by modifying polymeric dispersing agents such that they have a polydispersity significantly lower than the typical minimum polydispersity (often around 1.8) that are present in the best quality polymeric dispersing agents currently available. Indeed since it is much easier to make polymers having high PD values than low PD values the possibility of trying to make them on a commercial scale has probably never occurred to anyone previously as no one has ever previously recognised that there is any particular value in them.

Insoluble low molecular weight polymers having low polydispersity values are described in European Patent Specification 68887 but since such polymers are insoluble they cannot be used as pigment dispersants.

We have now found that low molecular weight water soluble polymeric dispersants have greatly improved pigment dispersing properties if the polymer has a much narrower range of molecular weight than has previously been used, that is to say if PD is reduced substantially below the conventional values of 1.8 and above to a value below 1.5. Thus we have found that for any particular purpose optimum results are obtained if the polymer consists of molecules of very limited range of chain lengths. The presence of molecules of other chain lengths is disadvantageous for two reasons. First, and most important, these other molecules counteract the beneficial effects of the preferred molecules, presumably because of preferential absorption of some other deleterious or antagonistic mechanism. Secondly, these other molecules dilute the polymer so that it contains less than the theoretical maximum of the preferred molecules.

According to the invention a dispersion of pigment in an aqueous medium contains a dispersing agent for the pigment which is a water soluble polymer formed from one or more ethylenically unsaturated monomers and contains acid groups selected from carboxyl and sulphonic groups, or is a water soluble salt thereof, and has a polydispersity of below 1.5 and has a low molecular weight. Mw is normally at least about 1,500 and can be up to about 6,000 but preferably it is up to about 5,000. Particularly preferred products are those having PD below 1.4 and Mw 1,500 to 4,000.

Generally PD = 1.05 to 1.45 and in particular from 1.1 to 1.4. The best results are obtained with PD below 1.4 and preferably below 1.35. Although it is desirable for the value to be as close to 1 as possible it is generally acceptable for it to be above 1.25.

The polymer is preferably acrylic acid or copolymer thereof with AMPS (2-acrylamido-2-methyl propane sulphonic acid). Throughout this specification it must be understood that any acid polymer can be present in the form of a partial or complete salt with an alkali metal, often sodium, or ammonia or an amine or other cation that yields a water soluble salt. For instance the polymer may be a copolymer of acrylic acid with a salt of ANPS or it may be a complete salt of acrylic acid AMPS copolymer or a partial or complete salt of acrylic acid. All molecular weights herein are measured as the full sodium salt.

Although these are the preferred polymers, other water soluble polymers can be used in the invention, generally

being polymers obtained by polymerisation of an ethylenically unsaturated monomer that contains acid groups either alone or with other ethylenically unsaturated monomeric material. Oligomers formed from the corresponding monomers may be used in place of the monomers. The acid groups are generally carboxylic acid or sulphonic acid groups. The monomers are often acrylic monomers and therefore preferred acidic monomers include one or more of methacrylic acid or, especially, acrylic acid or 2-acrylamido-2-methyl propane sulphonic acid, but a wide range of other polymerisable acidic monomers can be used, for instance maleic acid or vinyl sulphonic acid. Any comonomers that can be copolymerised, in the amounts present, with the acidic monomer or monomers to form a water soluble polymer can be used and include monomers such as acrylamide, acrylonitrile and acrylic esters. Generally at least 50% by weight and often at least 80% by weight of the monomers from which the polymer is formed are acidic monomers. The polymer is generally a linear polymer.

Within the broad inventive concept defined above there are certain areas of particular value. As mentioned above certain low molecular weight vinyl acetate copolymers are mentioned in British Specification No. 1,414,964 for dispersing pigments and as grinding dispersants for pigments. In practice however these have not made any significant commercial impact and the dispersants normally used are the low molecular weight polyacrylic acids having PD generally above 1.8.

According to one aspect of the invention a dispersion in water of a pigment includes, as dispersing agent, a polyacrylic acid having PD below 1.5 and Mw in the range about 1,500 to about 3,300, preferably 1,500 to 3,000 and most preferably in the range about 1,800 to about 2,200, with best results generally being achieved at values of around 2,000. PD preferably is in the range 1.05 to 1.4, most preferably 1.1 to 1.3 or 1.35.

These dispersions can conveniently be made simply by blending particulate pigment with water in the presence of the dispersing agent, the amounts of pigment and dispersing agent being conventional. For instance the amount of dispersing agent is often from 0.05 to 0.3% by weight dry polymer based on dry pigment. The amount of pigment is often from 10 to 90% by weight of the dispersion, most preferably 50 or 60 up to 80% by weight. The pigment will be chosen having regard to the intended use of the dispersion. Often the dispersion is used in the paper industry, for instance for paper coating, and suitable pigments include china clay, talc, titanium dioxide and precipitated calcium carbonate. The particle size is generally in the range 0.5 to 100 microns, preferably 1 to 50 microns.

It is well recognised that there is a particular problem in making concentrated pigment dispersions by grinding calcium carbonate in water, particularly if very fine particle sizes are required. This is discussed in our European Patent Specification 108842 and in the literature to which that refers. We describe in that how sodium polyacrylate Mw 2,800 is conventionally used but that improved results can be obtained using acrylic acid-AMPS copolymers, the best result (lowest viscosity) being shown at Mw around 5,700.

According to a second aspect of the invention a dispersion of calcium carbonate in water is made by grinding calcium carbonate in water in the presence of a dispersing agent that is a polyacrylic acid having PD below 1.5 and Mw in the range about 2,500 to about 4,500, most preferably in the range 3,300 to 3,900.

According to a third aspect of the invention a dispersion of calcium carbonate in water is made by grinding calcium carbonate in water in the presence of a dispersing agent that is a copolymer of acrylic acid and AMPS having PD below 1.5 and Mw in the range about 1,500 to about 3,500, most preferably about 2,250 to about 2,750. The preferred molecular weight for the homopolymer is about 3,600 and the preferred molecular weight for the copolymer is about 2,500. The proportions by weight of acrylic acid to AMPS are preferably 99:1 to 50:50.

When grinding calcium carbonate in accordance with either of these aspects of the invention PD is preferably from 1.05 to 1.4, most preferably 1.1 to 1.3.

The grinding is preferably by sand grinding and the resultant particle size of the calcium carbonate (marble) is preferably mainly below 2 μ m. The amount of pigment in the resultant dispersion is preferably above 70% and most preferably is above 75%. For more description of suitable grinding techniques, particle sizes and concentrations reference should be made to EP-A-108842 and to the literature referred to therein. Thus the particulate material in the dispersion preferably consists of at least 72%, and most preferably 74 to 80%, by weight of dispersion of calcium carbonate in the form of ground particles of which at least 87% by weight are below 2 μ m in size.

In US Patent Specification 3840487 and in British Patent Specification 1505555 various aqueous dispersion paints comprising of pigment and a low molecular weight polymeric dispersing agent are described. For the purposes described in those specifications particular polyacrylic acid-ester copolymers are used but in many other instances polyacrylic acid homopolymer, and in particular Dispex N40 is generally regarded as entirely satisfactory. We now find better results are obtained using the novel polymer defined herein. In particular, according to a fourth aspect of the invention an aqueous dispersion paint comprises a pigment, a binder for the paint and a dispersing agent for the pigment, the dispersing agent being polyacrylic acid having PD below 1.5 and Mw in the range about 1,500 to about 6,000. PD is preferably from 1.05 to 1.4, most preferably 1.1 to 1.3 and the molecular weight is preferably in the range 1,500 to 4,500. The aqueous medium of the paint may be water or a mixture of water with a polar solvent, generally a glycol.

The pigment generally is titanium dioxide, china clay, or calcium carbonate and generally has a particle size of 0.1

to 50 microns, preferably 0.2 to 25 microns. The amount of pigment in the paint may be conventional, typically from 5 to 50% by weight of the paint. The binders and other components in the paint may be conventional, for instance as described in US Patent Specification 3840487 and British 1505555.

The invention also includes the preferred, novel water soluble polymeric dispersing agents suitable for use as the dispersing agent in an aqueous pigment dispersion and that is polyacrylic acid or a copolymer of acrylic acid and AMPS characterized in that the polymer has PD below 1.5 but at least 1.1 and Mw, measured on the sodium salt, of from about 2,500 to about 4,500 when the polymer is polyacrylic acid or about 1,500 to about 3,500 when the polymer is a copolymer of acrylic acid and AMPS.

The low polydispersity values required in the invention can be obtained by various techniques. For instance, a polymer can be made by a conventional polymerisation technique, for instance, solution polymerisation, to obtain a product having a high polydispersity value (typically 2 or higher) and may then be subjected to careful fractional precipitation so as to obtain fractions each having a polydispersity below 1.5. The conditions for conducting the fractional precipitation must be such as to give this low polydispersity and so must consist of isothermal non solvent addition as detailed in Chapter B1 of "Polymer Fractionation" Ed. Manfred Cantow.

Another way of obtaining the desired polymer is to conduct its synthesis under conditions that lead to its formation. For instance the polymer may be made by solution polymerisation in the presence of isopropanol as chain regulator. The process must be carried out under very uniform and closely monitored conditions, for instance controlled feeds of monomer, and initiator and uniform temperature throughout. If the product that is obtained has a polydispersity above the desired value it must be rejected or treated in such a manner as to reduce its polydispersity.

Another way of obtaining the desired polymer is to make an insoluble acrylate polymer having the desired PD and Mw values, for instance as described in Example 40 of European Patent Specification 68887 and then to hydrolyse the acrylate to the free acid, for instance by reaction with sodium hydroxide at 85°C for 6 hours or as long as is necessary to achieve hydrolysis, the reaction generally being conducted in the presence of methanol as a diluent. The preferred method is the method described in our copending application No 84303332.5 (EP 0 127 388 A). In this method a solution is formed in a blend of water and a polar solvent of a water soluble polymer containing neutralised acid groups and the solution is separated into an aqueous phase containing a higher molecular weight fraction of the polymer and an organic phase containing a lower molecular weight fraction of the polymer, and in this process the polar solvent is a C₁ to C₅ alcohol, the acid groups are neutralised with cations selected from sodium, potassium, lithium and ammonium and the molar proportion of neutralised acid groups is 10 to 55% when the cation is selected from sodium and potassium, 10 to 70% when the cation is ammonium and 30 to 90% when the cation is lithium.

The precise split between the lower and higher molecular weight fractions can be selected by altering the process conditions, and in particular the degree of neutralisation, and so the invention provides, for the first time, a simple process by which an acidic, water soluble, polymer can be fractionated into preselected molecular weight fractions. Unlike prior processes where the organic fraction is usually rejected, in the invention both fractions of polymer are commercially useful and so are recovered and used, the fraction in the organic phase being useful where lower molecular weights are desired and the fraction in the aqueous phase being useful where higher molecular weights are desired.

The polymer may have been made by any conventional polymerisation process and may have then been isolated, for instance as a solid, from any liquid phase in which it was formed, and then redissolved in the aqueous organic alkaline solution used in the invention. Generally however the process of the invention is conducted on a solution of the polymer obtained by solution polymerisation of the appropriate monomers. The preferred solution polymerisation medium is an aqueous solution containing appropriate initiators or other polymerisation promoters, for instance water soluble peroxides and persulphates, or redox catalysts or catalysts for photopolymerisation and will generally include an organic solvent, for instance as a molecular weight regulator. Other known molecular weight regulators may be included in the solution if desired.

When the solution of polymer is made by polymerisation in a mixture of water and organic solvent this organic solvent may serve as the organic liquid for use in the invention. A very common solvent in solution polymerisations is isopropanol and blends of water and isopropanol are suitable for many processes according to the invention.

Irrespective of whether the solution is made by blending preformed polymer, water, organic solvent and alkali or by adding alkali to the reaction product of polymerisation in aqueous organic liquid, or in any other manner, the process of the invention requires that phase separation should be brought about between aqueous and organic phase in the presence of the specified solvents and the specified amounts of the specified cations. If other solvents, other cations or other amounts of the specified cations are used the process generally will not give the variable fractionation of the invention but instead will either give no useful results or will merely strip oligomer and monomer from the product. For instance it is not possible to select the degree of fractionation if the organic solvent is acetone or tetrahydrofuran or if the cation is provided by an amine such as ethylamine.

The degree of neutralisation of the acid groups controls the fractionation. The results obtained in any particular process will depend upon, inter alia, the concentrations, the polymer type and the solvent but there is a minimum

degree of neutralisation below which substantially no fractionation occurs and the system may instead remain as a homogeneous solution. When the cation is sodium, potassium or lithium the degree of neutralisation will normally be at least 10%, often at least 15% and preferably at least 25% whilst if the cation is lithium the degree of neutralisation will normally have to be at least about 30%, preferably at least 40% and generally at least 50%. If the degree of neutralisation is too high the size of the lower molecular weight fraction is unacceptably low. When the cation is sodium or potassium the degree of neutralisation will normally be below 55%, preferably below 50% and most preferably below 40%. When the cation is ammonium the degree of neutralisation will normally be below 70%, preferably below 60% and most preferably below 50%. When the cation is lithium the degree of neutralisation will normally be below 90%, and preferably below 70%.

In any particular process the size of, for instance, the higher molecular weight fraction can be increased (with consequential reduction in its average molecular weight and consequential reduction in the size and the average molecular weight of the lower molecular weight fraction) by increasing the amount of alkali and conversely the size of the low molecular weight fraction can be increased by reducing the amount of alkali.

The process conditions are preferably selected such that each fraction contains from 20 to 80%, and most preferably 30 to 70%, by weight of the starting polymer.

The partial neutralisation of the acidic polymer is normally achieved by adding a compound that will provide the chosen cation, the compound usually being a hydroxide, in the selected amount to the dissolved polymer. Mixtures of two or more of the four cations may be utilised, in which event the proportions will be selected such that they have the same effect as the amounts specified for the individual cations.

For any particular polymer, the degree of fractionation is dependent not only on the degree of neutralisation and the type of cation but also upon the concentration of the polymer and the choice and amount of the alcohol. The alcohol is preferably isopropanol but propanol and other alcohols, especially C₂ to C₅ alcohols, may be used. The proportion water:alcohol by weight is preferably from 1:0.2 to 1:5, most preferably 1:0.5 to 1:2 with best results generally being achieved, especially when the alcohol is isopropanol and the cation is sodium, when the proportion is about 1:1. The proportions should be selected such that, having regard to the degree and nature of neutralisation, each of the phases will have a polymer concentration of at least 5%, generally at least 10% and preferably at least 15% by weight of the phase.

The amount of the polymer (measured as the acid polymer) is normally at least 5% by weight based on the weight of polymer, alcohol and water (including water introduced with the alkali) and preferably is at least 10%. The concentration must not be so high that the system is so viscous that mixing and phase separation is significantly impeded and so is generally below 30%. Preferably the concentration is 15 to 25% by weight.

The phase separation may also be affected by the temperature at which the process is conducted. This may be between 15 and 80°C but preferably is between 30 and 70°C.

The process may be conducted by combining the essential components of the solution in any convenient manner, for instance by adding aqueous alkali to the aqueous organic reaction product obtained by polymerisation of the monomer or monomers in aqueous organic solution. The process may be conducted continuously or batchwise. Depending upon the degree of neutralisation, and type and strength of base, the concentration of the polymer, the amount of solvent and the temperature the phase separation may occur rapidly or slowly. For instance it may occur substantially instantaneously or it may be necessary to leave the system to stand for periods of, for instance, 5 minutes to 2 hours, typically 30 minutes to 1 hour. The separation may be conducted batchwise or continuously, with the mix being fed through a conventional separation column or separation reactor.

The two phases are kept separate, may be fully neutralised with the same or different alkali and organic solvent may be stripped from the organic phase by distillation.

Each of the polymer fractions is recovered for subsequent commercial use.

The very low molecular weight fractions obtained by this technique have a particular value as agents for inhibiting the build-up of scale, and settlement of scale, and in particular as desalination aids. For instance we have established that the maximum level of alkalinity that can be maintained in solution is increased if PD is reduced. Thus best results are achieved if Mw is from 350 to 1,000 and PD is below 1.5, most preferably 1.05 to 1.3.

In the following examples, Example 1 demonstrates how a polymer may be made to the desired PD and Mw values by careful polymerisation, and Examples 2 and 3 demonstrate how the polymer may be obtained by partial neutralisation and fractionation.

Example 1

To a 700 cm³ resin pot equipped with thermometer, stirrer and external heating, three separate mixtures were continuously added over a 6 hour period.

Feed 1 consisted of: 340 g glacial acrylic acid in 226 g water

Feed 2 10.5 g 100 vol. hydrogen peroxide and 57.1 g water
Feed 3 28 g thioglycolic acid and 38.6 g water.

The pot contents were maintained at reflux temperature throughout the addition and then for a further hour before being cooled. The percentage unpolymerised acrylic acid was determined by Gas Liquid Chromatography and shown to be 0.3% of the amount added.

The remaining polymer was fully neutralised by the addition of 46.6% sodium hydroxide and the final product diluted to give a 40% w/w sodium polyacrylate solution.

The viscosity of the product at 25% was 12.1 cS (suspended level viscometer, No. 2, 25°C). GPC analysis showed Mw = 1740, M = 1321, Polydispersity = 1.32.

Example 2

A 23% by weight solution of polyacrylic acid in a blend of equal parts by weight isopropanol and water was prepared by polymerisation of acrylic acid using ammonium persulphate as initiator, in conventional manner. Samples of the product were extracted while other samples were neutralised by the addition of varying amounts of sodium hydroxide, introduced as a 46% by weight aqueous solution. Each of the samples, after the addition of sodium hydroxide, was allowed to stand for sufficient time for an aqueous phase to separate from an organic phase (that probably contained some water) and these phases were then separated from one another in conventional manner. Each phase was then fully neutralised with sodium hydroxide and the residual alcohol was removed by distillation. The yield of polymer in each of the phases was recorded.

Example 3

A 20% solution of polyacrylic acid having Mw of 3131 and PD (polydispersity) of 1.677 was dissolved in 50/50 w/w isopropanol/water was neutralised with various basic compounds and the two layers separated. The amount and molecular weight of the polymer in each layer was determined. The results are shown in Table 1.

TABLE 1

Base	% Neutralisation	Aqueous layer			Organic layer		
		% Extracted	Mw	P.D.	% Extracted	Mw	P.D.
NaOH	25	75.2	3833	1.30	24.8	1452	1.402
NH ₄ OH	25	55.6	4025	1.30	44.4	1689	1.34
LiOH	25	NO SEPARATION					
LiOH	50	50.2	3957	1.427	49.8	1783	1.44
KOH	25	63.5	3649	1.56	36.5	1402	1.49
NaOH	15	20.6	3976	1.49	79.4	2027	1.63
NaOH	50	95.7	3688	1.51	4.3	Very low	
NaOH	75	99.3	3376	1.53	0.7	Very low	

Example 4

The products obtained in Example 2 were adjusted to 40% active solids and compared as marble grinding aids as described in Example 11 of British Patent Specification No. 1,414,964. The results are set out in Table 2.

TABLE 2

Percent Neutralisation	Yield Percent		Aqueous Layer Milling index
	Organic	Aqueous	
0*			0.25
10	87.2	12.8	-
15	79.3	20.7	-

* This product is made in conventional manner by full neutralisation followed by removal of the organic phase by distillation, and so there is no fractionation.

TABLE 2 (continued)

Percent Neutralisation	Yield Percent		Aqueous Layer Milling index
	Organic	Aqueous	
25	23.1	76.9	1.94
50	4.0	96.0	2.33
75	0.7	99.3	1.22
100	0.5	99.5	0.37

In the described test a milling index value of around 0.5 is generally satisfactory as it indicates commercially acceptable properties for preventing gelation of the marble dispersion.

It is apparent from the table that after full neutralisation almost all the polymer is in the aqueous phase but that substantial amounts of polymer go into the organic phase at low degrees of neutralisation. It is also very notable that the milling index is greatly improved even when the amount of polymer that is in the organic phase, instead of the aqueous phase, is quite low. For instance at 50% neutralisation the amount of polymer in the organic phase is low but the milling index is about 5 times what would be considered to be commercially adequate. At higher degrees of neutralisation only a very low amount of polymer goes into the organic phase.

Example 5

A polymer was prepared by conventional polymerisation technique as a 23% solution of acrylic acid in equal amounts of isopropanol and water was neutralised to 25% with aqueous sodium hydroxide after polymerisation. This caused the reaction mixture to separate into two phases. These were separated and the polymer present in such phase was recovered after removal of the isopropanol by distillation. The samples were fully neutralised with sodium hydroxide solution and adjusted to 40% active as sodium polyacrylate.

An unfractionated control polymer was also prepared from the original unneutralised polymer in isopropanol/water by removing the isopropanol by distillation and fully neutralising with sodium hydroxide and adjusting to 40% active as sodium polyacrylate.

The products were evaluated as dispersants for titanium dioxide, having particle size 97% below 2 μ m, at 75% w/w slurry solids content by recording the slurry viscosity (cP) at 0.6, 0.8 and 1% dry polymer based on dry pigment. The results are given in Table 3.

TABLE 3

Neutralisation %		Mw	Mn	PD	Slurry Viscosity (cP)		
					0.6	0.8	1.0
100	Control	3161	2019	1.565	-	1320	1380
25	Aqueous phase	4236	2795	1.515	-	-	2600
25	Organic phase	1795	1367	1.314	3500	700	340

Example 6

Samples of narrow polydispersity sodium polyacrylates of decreasing molecular weight were evaluated as dispersant for china clay at 64% w/w slurry solids content at pH 6.8-7.0 and at various dosages, as in Example 4. The results are given in Table 4.

TABLE 4

Mw	Mn	PD	Slurry Viscosity (cP)						
			0.10	0.12	0.14	0.16	0.18	0.20	0.22
5543	4817	1.15	-	-	1567	359	290	321	376
4876	3907	1.25	-	1483	643	285	296	330	405
4447	3592	1.24	-	933	423	255	269	312	361

TABLE 4 (continued)

Mw	Mn	PD	Slurry Viscosity (cP)						
			0.10	0.12	0.14	0.16	0.18	0.20	0.22
4053	3273	1.24	-	703	263	225	249	284	-
3202	2709	1.18	-	234	198	211	233	271	-
2144	1901	1.13	533	183	190	207	231	266	-
1065	834	1.28	637	226	198	201	213	230	-

The results show that the most effective sodium polyacrylates for china clay dispersants lie between a molecular weight of 1000-3000. Preference has been given to a molecular weight of approximately 2000.

Example 7

The samples of sodium polyacrylate of similar molecular weight but varying polydispersity were evaluated as marble milling aids. The results are expressed as Milling Index using a test method as described in Example 11, British Patent No. 1,414,964 are shown in Table 5.

TABLE 5

Mw	PD	Milling Index
3225	1.38	2.54
3105	1.52	1.23
3229	1.63	0.29
3358	2.01	<0.20

The results show that the effectiveness of sodium polyacrylate on marble milling is dependent on polydispersity. The lower the polydispersity the more effective the product.

Example 8

It can be shown that the interrelationship between molecular weight and polydispersity of a sodium AMPS/sodium acrylate (20/80 w/w) copolymer has a crucial effect when the product is evaluated as a marble grinding aid according to Example 11 of British Patent Specification No. 1,414,964. The interrelationship between these parameters is shown in Table 6.

TABLE 6

	Mw	PD	Milling Index
Low molecular weight low polydispersity	2351	1.26	2.6
	2630	1.34	2.4
Low molecular weight high polydispersity	2834	1.6	0.38
	3151	1.55	0.44
High molecular weight low polydispersity	7193	1.40	0.67
	4625	1.47	0.81
High molecular weight high polydispersity	6265	1.64	0.64
	5836	1.53	0.77

The results show that polymers of low molecular weight with narrow polydispersity are the most effective marble grinding aids. The optimum molecular weight lies between 1500 and 3500 with preference given to polymers with a molecular weight of 2500.

Example 9

Samples of sodium polyacrylate of similar molecular weight but varying polydispersity were evaluated as in Example 4 as dispersants for precipitated calcium carbonate at 70% w/w slurry solids content. The results are given in

Table 7.

TABLE 7

Mw	PD	Brookfield Viscosity						
		0.150	0.175	0.200	0.225	0.250	0.275	0.300
3226	1.38	117	114	130	177	114	107	104
3105	1.52	120	134	167	178	164	130	127

Claims

1. A dispersion of pigment in an aqueous medium containing a dispersing agent for the pigment and in which the dispersing agent is a water soluble polymer formed from one or more ethylenically unsaturated monomers and containing acid groups selected from carboxyl and sulphonic groups, or a water soluble salt thereof, characterised in that the polymer has PD below 1.5 and Mw (measured as the sodium salt) of from about 1,500 to about 6,000.
2. A dispersion according to claim 1 in which PD is 1.05 to 1.4 and Mw is below 4,000.
3. A dispersion according to claim 1 in which the polymer is polyacrylic acid or a copolymer of acrylic acid and AMPS, or a water soluble salt thereof.
4. A dispersion according to claim 1 or claim 2 in which the polymer is polyacrylic acid, or a water soluble salt thereof, having Mw, measured as the sodium salt, of below about 3,300.
5. A dispersion according to claim 4 in which Mw is in the range 1,800-2,200.
6. A dispersion according to claim 4 or claim 5 in which the pigment is selected from china clay, talc, titanium dioxide and precipitated calcium carbonate and has a particle size in the range 1 to 50 microns.
7. A dispersion according to claim 6 and which is a paper coating dispersion having a pigment concentration of 50 to 80% by weight.
8. A dispersion according to claim 1 or claim 2 made by grinding calcium carbonate in water containing the polymer and in which the polymer is selected from (a) polyacrylic acid, or a water soluble salt thereof, having Mw, measured as the sodium salt, in the range about 2,500 to about 4,500 and (b) a copolymer of acrylic acid and AMPS, or a salt thereof, having Mw, measured on the sodium salt, in the range about 1,500 to about 3,500.
9. A dispersion according to claim 8 in which the amount of calcium carbonate in the dispersion is above 70% by weight and the particle size is mainly below 2 μ m.
10. A dispersion according to claim 8 in which the calcium carbonate is present in an amount of at least 71% by weight and at least 87% by weight of the particles are less than 2 μ m in size.
11. A dispersion according to any of claims 8 to 10 in which the polymer is polyacrylic acid, or a water soluble salt thereof, and Mw is in the range about 3,300 to about 3,900.
12. A dispersion according to any of claims 8 to 10 in which the polymer is a copolymer of acrylic acid and AMPS in the weight ration 99:1 to 50:50 and Mw is in the range about 2,250 to about 2,750.
13. An aqueous dispersion according to claim 1 or claim 2 that is a dispersion paint that includes a binder for the paint and in which the polymer is polyacrylic acid having Mw, measured on the sodium salt, in the range about 1,500 to about 5,000.
14. A dispersion according to claim 13 in which the pigment is selected from titanium dioxide, china clay and calcium carbonate and has a particle size of 0.2 to 25 microns.
15. A water soluble polymeric dispersing agent suitable for use as the dispersing agent in an aqueous pigment dis-

persion and that is polyacrylic acid or a copolymer of acrylic acid and AMPS characterised in that the polymer has PD below 1.5 but at least 1.1 and Mw, measured on the sodium salt, of from about 2,500 to about 4,500 when the polymer is polyacrylic acid or about 1,500 to about 3,500 when the polymer is a copolymer of acrylic acid and AMPS.

- 5 16. A polymeric dispersing agent according to claim 15 which has PD up to 1.4.
17. A polymeric dispersing agent according to claim 15 or claim 16 made by a process comprising aqueous solution polymerisation of the one or more monomers in the presence of isopropanol as chain regulator.

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Patentansprüche

- 15 1. Dispersion von Pigment in einem ein Dispergiermittel für das Pigment enthaltenden wäßrigen Medium, worin das Dispergiermittel ein wasserlösliches Polymer, gebildet aus einem oder aus mehreren ethylenisch ungesättigten Monomeren, mit einem Gehalt an sauren Gruppen, ausgewählt unter Carboxyl- und Sulfongruppen, oder ein wasserlösliches Salz hiervon ist, dadurch gekennzeichnet, daß das Polymer einen PD-Wert unter 1,5 und ein Mw (ermittelt als Natriumsalz) von etwa 1.500 bis etwa 6.000 aufweist.
- 20 2. Dispersion nach Anspruch 1, worin der PD-Wert 1,05 bis 1,4 beträgt und das Mw unter 4.000 liegt.
3. Dispersion nach Anspruch 1, worin das Polymer Polyacrylsäure oder ein Copolymer aus Acrylsäure und AMPS oder ein wasserlösliches Salz hiervon ist.
- 25 4. Dispersion nach Anspruch 1 oder 2, worin das Polymer Polyacrylsäure oder ein wasserlösliches Salz hiervon mit einem Mw, gemessen als Natriumsalz, von unter etwa 3.300 ist.
5. Dispersion nach Anspruch 4, worin das Mw im Bereich 1.800 bis 2.200 liegt.
- 30 6. Dispersion nach Anspruch 4 oder 5, worin das Pigment unter Porzellanerde, Talk, Titandioxid und gefälltem Calciumcarbonat ausgewählt ist und eine Teilchengröße im Bereich 1 bis 50 µm aufweist.
7. Dispersion nach Anspruch 6, welche eine Papierbeschichtungsdispersion mit einer Pigmentkonzentration von 50 bis 80 Gewichts-% ist.
- 35 8. Dispersion nach Anspruch 1 oder 2, hergestellt durch Mahlen von Calciumcarbonat in das Polymer enthaltendem Wasser, worin das Polymer ausgewählt ist unter
- (a) Polyacrylsäure oder einem wasserlöslichen Salz hiervon mit einem Mw, gemessen als Natriumsalz, im Bereich von etwa 2.500 bis etwa 4.500 und
- 40 (b) einem Copolymer von Acrylsäure und AMPS oder einem Salz hiervon mit einem Mw, gemessen am Natriumsalz, im Bereich von etwa 1.500 bis etwa 3.500.
9. Dispersion nach Anspruch 8, worin die Calciumcarbonatmenge in der Dispersion über 70 Gewichts-% beträgt und die Teilchengröße überwiegend unter 2 µm liegt.
- 45 10. Dispersion nach Anspruch 8, worin das Calciumcarbonat in einer Menge von wenigstens 71 Gewichts-% vorliegt und wenigstens 87 Gewichts-% der Teilchen kleiner als 2 µm sind.
11. Dispersion nach einem der Ansprüche 8 bis 10, worin das Polymer Polyacrylsäure oder ein wasserlösliches Salz hiervon ist und das Mw im Bereich von etwa 3.300 bis etwa 3.900 liegt.
- 50 12. Dispersion nach einem der Ansprüche 8 bis 10, worin das Polymer ein Copolymer aus Acrylsäure und AMPS im Gewichtsverhältnis 99:1 bis 50:50 ist und das Mw im Bereich von etwa 2.250 bis etwa 2.750 liegt.
- 55 13. Wäßrige Dispersion nach Anspruch 1 oder 2, welche eine Dispersionsfarbe ist, die ein Bindemittel für die Farbe enthält und worin das Polymer Polyacrylsäure mit einem Mw, gemessen am Natriumsalz, im Bereich von etwa 1.500 bis etwa 5.000 ist.

14. Dispersion nach Anspruch 13, worin das Pigment ausgewählt ist unter Titandioxid, Porzellanerde und Calciumcarbonat und eine Teilchengröße von 0,2 bis 25 µm aufweist.
15. Wasserlösliches polymeres Dispergiemittel, das sich als Dispergiemittel in einer wäßrigen Pigmentdispersion eignet und bei dem es sich um Polyacrylsäure oder ein Copolymer aus Acrylsäure und AMPS handelt, dadurch gekennzeichnet, daß das Polymer einen PD-Wert unter 1,5, aber von mindestens 1,1 und ein Mw, gemessen am Natriumsalz, von etwa 2.500 bis etwa 4.500, wenn das Polymer Polyacrylsäure ist, oder von etwa 1.500 bis etwa 3.500, wenn das Polymer ein Copolymer aus Acrylsäure und AMPS ist, aufweist.
16. Polymeres Dispergiemittel nach Anspruch 15, das einen PD-Wert bis zu 1,4 aufweist.
17. Polymeres Dispergiemittel nach Anspruch 15 oder 16, hergestellt durch ein Verfahren, das eine Polymerisation des einen oder der mehreren Monomere in wäßriger Lösung in Gegenwart von Isopropanol als Kettenregler umfaßt.

Revendications

1. Dispersion de pigment dans un milieu aqueux contenant un agent dispersant pour le pigment et dans laquelle l'agent dispersant est un polymère soluble dans l'eau formé à partir d'un ou de plusieurs monomères éthyléniquement insaturés et contenant des groupes acides choisis parmi les groupes carboxyliques et sulfoniques, ou un sel soluble dans l'eau dudit polymère, caractérisée en ce que le polymère a une valeur PD inférieure à 1,5 et une valeur Mw (mesurée sur le sel de sodium) d'environ 1 500 à environ 6 000.
2. Dispersion selon la revendication 1, dans laquelle la valeur PD est de 1,05 à 1,4 et la valeur Mw est inférieure à 4 000.
3. Dispersion selon la revendication 1, dans laquelle le polymère est l'acide polyacrylique ou un copolymère d'acide acrylique et d'AMPS, ou un sel soluble dans l'eau de celui-ci.
4. Dispersion selon la revendication 1 ou 2, dans laquelle le polymère est l'acide polyacrylique, ou un sel soluble dans l'eau de celui-ci, ayant une valeur Mw, mesurée sur le sel de sodium, inférieure à environ 3 300.
5. Dispersion selon la revendication 4, dans laquelle la valeur Mw est dans l'intervalle de 1 800 à 2 200.
6. Dispersion selon la revendication 4 ou la revendication 5, dans laquelle le pigment est choisi parmi le kaolin, le talc, le dioxyde de titane et le carbonate de calcium précipité et a une taille de particules comprise dans l'intervalle de 1 à 50 µm.
7. Dispersion selon la revendication 6, et qui est une dispersion d'enduction du papier ayant une concentration en pigment de 50 à 80% en poids.
8. Dispersion selon la revendication 1 ou la revendication 2, préparée par broyage du carbonate de calcium dans l'eau contenant le polymère et dans laquelle le polymère est choisi parmi (a) l'acide polyacrylique, ou un sel soluble dans l'eau de celui-ci, ayant une valeur Mw, mesurée sur le sel de sodium, dans l'intervalle d'environ 2 500 à environ 4 500, et (b) un copolymère d'acide acrylique et d'AMPS, ou un sel de celui-ci, ayant une valeur Mw, mesurée sur le sel de sodium, comprise dans l'intervalle d'environ 1 500 à environ 3 500.
9. Dispersion selon la revendication 8, dans laquelle la quantité de carbonate de sodium dans la dispersion est supérieure à 70 % en poids et la taille de particules est principalement inférieure à 2 µm.
10. Dispersion selon la revendication 8, dans laquelle le carbonate de calcium est présent en une quantité d'au moins 71 % en poids et au moins 87 % en poids des particules ont une taille inférieure à 2 µm.
11. Dispersion selon l'une quelconque des revendications 8 à 10, dans laquelle le polymère est l'acide polyacrylique, ou un sel soluble dans l'eau de celui-ci, et la valeur Mw est comprise dans l'intervalle de 3 300 à environ 3 900.
12. Dispersion selon l'une quelconque des revendications 8 à 10, dans laquelle le polymère est un copolymère d'acide

acrylique et d'AMPS dans le rapport pondéral de 99:1 à 50:50 et la valeur Mw est comprise dans l'intervalle d'environ 2 250 à environ 2 750.

- 5 13. Dispersion aqueuse selon la revendication 1 ou 2, qui est une peinture en dispersion qui inclut un liant pour la peinture et dans laquelle le polymère est l'acide polyacrylique ayant une valeur Mw, mesurée sur le sel de sodium, comprise dans l'intervalle d'environ 1 500 à environ 5 000.
- 10 14. Dispersion selon la revendication 13, dans laquelle le pigment est choisi parmi le dioxyde de titane, le kaolin et le carbonate de calcium et a une taille de particules de 0,2 à 25 µm.
- 15 15. Agent dispersant polymère soluble dans l'eau utilisable comme agent dispersant dans une dispersion aqueuse de pigment et qui est l'acide polyacrylique ou un copolymère d'acide acrylique et d'AMPS caractérisé en ce que le polymère a une valeur PD inférieure à 1,5 mais d'au moins 1,1 et une valeur Mw, mesurée sur le sel de sodium, d'environ 2 500 à environ 4 500 lorsque le polymère est l'acide polyacrylique ou d'environ 1 500 à environ 3 500 lorsque le polymère est un copolymère d'acide acrylique et d'AMPS.
- 20 16. Agent dispersant polymère selon la revendication 15, qui a une valeur PD pouvant atteindre 1,4.
- 25 17. Agent dispersant polymère selon la revendication 15 ou la revendication 16, préparé par un procédé comprenant la polymérisation en solution aqueuse d'un ou de plusieurs monomères en présence d'isopropanol comme régulateur de chaîne.
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